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Z. V. Karyagina

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SPECTROPHOTOMETRIC STUDY OF THE INTENSIFICATION OF THE 5577 Å LINE IN ZODIACAL LIGHT

by Z. V. Karyagina

Different views are currently being held regarding the part played by the atmospheric component in the glow of zodiacal light. In the work of Karimov [1], a 20% increase in brightness was found for all three emission lines of nightglow in the spectrum of zodiacal light, as compared with their brightnesses at a point of the sky situated at an angular distance of 20° from the axis of zodiacal light.

In one of the latest articles by Roach et al [2], a study was made of the nightglow and glow of zodiacal light with a photoelectric photometer provided with four interference filters centered on the emission lines of night-glow in the portion of the continuous spectrum at 5300 Å. The criterion for the presence of glow intensification in the emission lines of zodiacal light was the ratio H_{em}/H_{5300}, where H_{em} is the brightness of the spectrum in the portion including the wavelength of the corresponding emission line, and H_{5300} is the same for the portion of the continuous spectrum from 5300 Å, free of emission lines. These quantities were obtained by calculating the intrinsic glow of the Earth's atmosphere and the scattered stellar light from the brightnesses observed; the brightnesses in the corresponding portions of the spectrum are expressed in units of brightness in the center of the Sun, and $\vartheta = 30°$ to $\vartheta = 100°$ were obtained for the angular distances from the Sun.

The following values of $\frac{H_{em}}{H_{5300}}$ were obtained for the portion $y\vartheta$ 5577 Å for values of ϑ of interest to us, in two days of observations:

 [redacted]

ϑ	14-15 December	18-19 November
45°	0,944	1,157
50	0,910	1,165
55	0,890	1,160
60	0,902	1,150
Average	0,915	1,158

The average value of the ratio $\frac{H_{5577}}{H_{5300}}$ for the two days is found to be 1.03.

The authors obtained this value of the ratio by averaging its values for all the angular distances from the Sun (from 30 to 100°), and it was found to be 1.00 (Table 11 in [2]) for all three of the emission lines observed; on the basis of the results obtained during these two days of observations, the author asserts that no intensification of the emission lines of the night sky in zodiacal light is observed. This is shown more graphically on the isophotic charts given in Fig. 13 in [2] for five days of observations, but, unfortunately, these charts are not accompanied by the data for the numerical value of the scale of the isophotes, and no indication is given of the number of points from which they were plotted. Thus, if the photometry was lacking in detail both with respect to the scale and the number of points used to trace the isophotes, the increase in the brightness of the 5577 line on the axis of zodiacal light could have been missed.

The aim of the present work was the determination of the brightness of the emission line of the night sky at 5577 Å in zodiacal light, as compared with its brightness at points of the sky to the north and south of its axis at the same zenithal distance.

The observations were made during March, 1956 at the Mountain Observatory of the Astrophysical Institute of the Academy of Sciences of the Kazakh SSR by means of the GAISh ultra-high-speed nebular spectrograph of N. N. Pariiskii's system. This spectrograph was made specifically for operation under experimental conditions. The instrument has interchangeable cameras: one with glass and the other with quartz optics. The optical diagram and general appearance of the spectrograph are given in Figs. 1 and 2

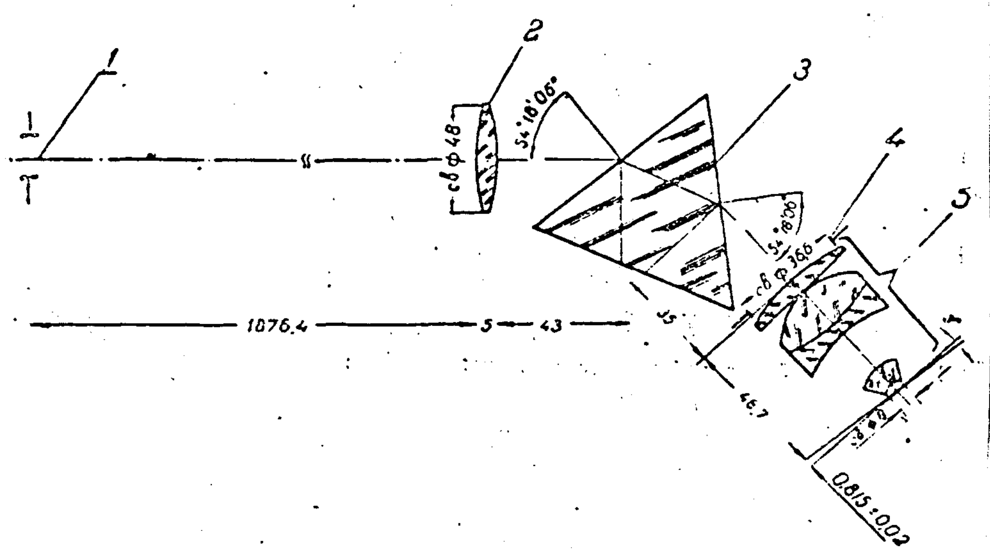

Fig. 1. Optical diagram of the high-speed nebular spectrograph.

In the present work, only the glass spectrograph was used. The focal distance of its collimator lens was 1,876 mm; the diameter of the collimator, 48 mm; the speed of the camera, 1:0.7; the focal distance of the camera lens, 25.6 mm; the height of the slit, 300 mm; the slit width could be varied from 0.2 to 50 mm. The reduction of the slit on the plate was 73 times. The focal distance of the collimator lens and the diaphragm aperture determines the averaging of the image of the celestial body by the spectrograph. For this spectrograph, the averaging circle in the sky has a diameter of about 1° for each point of the slit. The entire slit defined a strip 8° long and about 1° wide in the sky. The dispersion of the spectrograph at 5620 Å is 2500 Å/mm, and the length of the spectrum is 2 mm. The dispersion curve is given in Fig. 3.

The high speed of the spectrograph made it possible to obtain in 8 minutes, sufficiently dense negatives of the continuous spectrum of the night sky, and at the same time non-overexposed pictures of the emission lines on Kodak 103a D plates at a slit width of 3 mm.

At this slit width, the green line of the night sky, 5577 Å, was effectively separated from the yellow 5893 Å line, and the continuous spectrum on both of its sides was sufficiently dense to allow a reliable calculation of the brightness of the continuous spectrum from the brightness of the line.

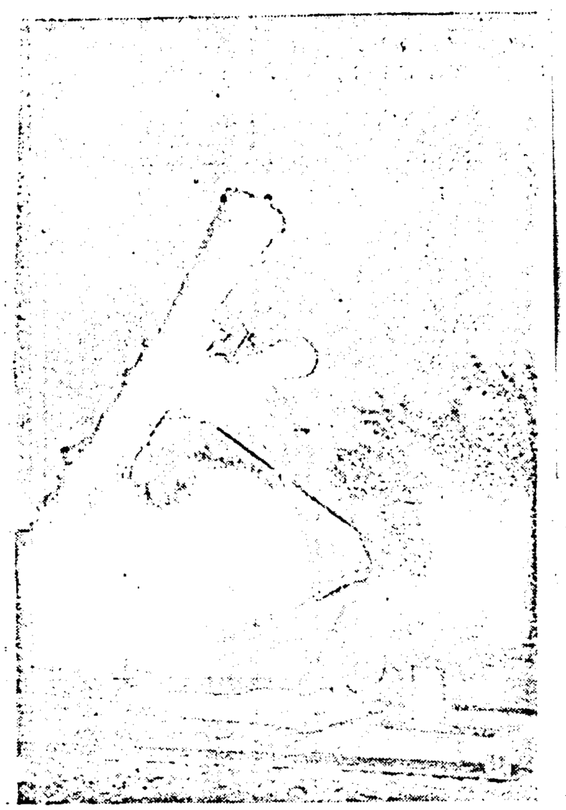

Fig. 2. General appearance of the high- speed nebular spectrograph.

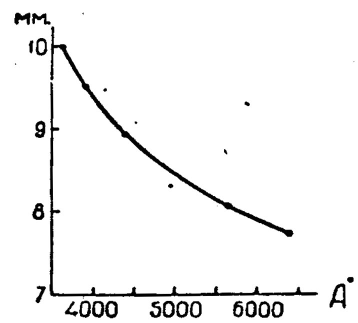

Fig. 3. Dispersion curve of the glass spectrograph.

The arrangement of the spectrograph tube allowed the latter to be rotated about the optic axis in such a way that the slit could define various directions in the sky. All the observations carried out in March, 1956 were made with the slit along the ecliptic plane.

The observations were usually begun immediately after twilight, when the Sun dipped to -20°, and were performed as follows: first, the spectrum of the sky to the north or south of the axis of zodiacal light was photographed (angular distance given by the almucantar, 35°), then the spectrum of zodiacal light was photographed, and again the spectrum of the sky on the opposite side of the axis of zodiacal light. All the photographs were made at a zenithal distance of the slit's center of 70°. On the average, about 8 photographs of the spectrum could be obtained in one evening. The photographs of zodiacal light corresponded to angular distances from the Sun of 45 to 60°. The considerable length of the slit made it possible to get spectra with two exposures simultaneously: 8 min and 4 min. To this end, a special attachment with shutters was mounted in front of the slit; four of the shutters were open during all of the 8 min, and the other four (through one), only 4 min (see Fig. 4).

Calibration photographs were obtained with a universal monochromator with a multistage platinum attenuator at the same exposures of 4 and 8 min and with different neutral filters placed in front of the bulb of the illuminator, in order to obtain a selection of calibration curves which were subsequently averaged out. The calibration curves were plotted for wavelengths of 5600, 5461, 5265, and 4930 Å. It was found that within the limits of accuracy they were parallel and could be averaged out. The transmission of the plates of the platinum attenuator was studied thoroughly under the same conditions. To this end, photographs of the spectra with the attenuator were specially obtained, and the calibration photographs were obtained by means of a tube photometer with different filters, viz: OS-12, ZhZS-1, SZS-8 and SS-4. A large number of photographs were obtained, half of which were processed by us and the other half by our collaborator at GAISh [P. K. Shternberg State Institute of Astronomy], L. M. Gindilis.

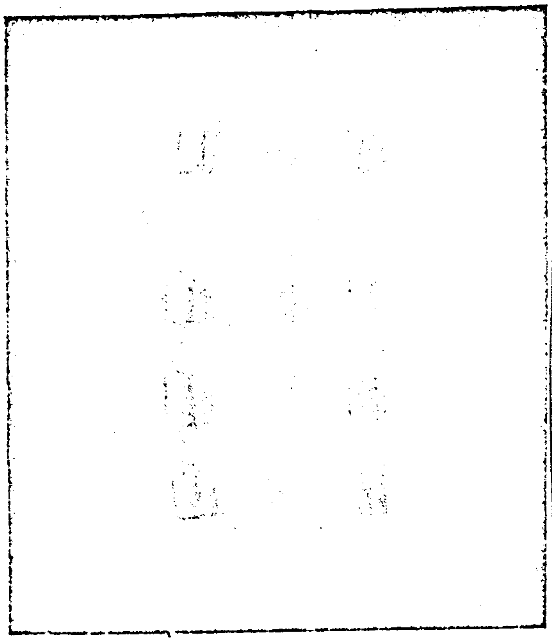

Fig. 4. Spectra of zodiacal light (right) and sky (left). Exposure, 4 min and 8 min.

Results of the study are given in Table 1.

Table 1.

Results of the Study of the Attenuator

1	2	3	4	5	6	7
1—2	0,189 ± 0,008	0,177 ± 0,007	0,182 ± 0,006	1	0,97	0,83
2—3	0,103 ± 0,005	0,142 ± 0,004	0,125 ± 0,020	2	1,15	1,00
3—4	0,137 ± 0,006	0,142 ± 0,005	0,140 ± 0,002	3	1,28	1,17
4—5	0,181 ± 0,005	0,152 ± 0,004	0,165 ± 0,015	4	1,42	1,34
5—6	0,138 ± 0,002	0,150 ± 0,003	0,143 ± 0,006	5	1,58	1,50
6—7	0,169 ± 0,005	0,154 ± 0,014	0,165 ± 0,007	6	1,73	1,69
7—8	0,084 ± 0,006	0,137 ± 0,007	0,108 ± 0,026	7	1,89	1,86
				8	2,00	2,00

The columns of Table 1 represent the following: 1st column, numbers of the plates for which the density differences were determined; 2nd column, density differences of pairs of these plates as determined by L. M. Gindilis; 3rd column, the same as determined by us; 4th column, averaged weighted density difference values from our determinations and those of Gindilis; 5th column, numbers of the plates; 6th column, values of densities of the plates, obtained from column 4, assuming the density of the 8th plate to be 2.00; 7th column, the same as in column 6 (from the data on the rating plate of the attenuator).

Table 1 gives the average densities of the plates of the attenuator for wave lengths λλ 5265 to 5780Å, in view of the fact that the transmission of the attenuator plates is independent of the wavelength between these limits. The errors shown in Table 1 are mean squares and were determined from 5 to 6 separate determinations. This study demonstrates that the scale of the attenuator is known within 1 to 2%.

The standardization involved the use of a constant luminophor whose energy distribution was determined by a tie-in with the stars.

The photometric analysis of the spectrum was done with an MF-2 microphotometer at a 0.3 mm slit width with a magnification of 30 X, which corresponded to 0.01 mm on the plate. The spectra were measured in the range from 5850 to 5200 Å. Over this wavelength range, the densities were determined at 50 points, and the contour of the 5577 Å line obtained was very definite. The continuous spectrum in the portion of the contour of the 5577 Å line was determined by interpolating its values to the right and left of the line. To verify its distortion due to the wings of the line, the instrumental contour was determined and compared with the contour of the 5577 Å line for the night sky; it was found that the continuous background is well defined, being undistorted by the line wings.

In further processing, the observed intensities were obtained in units of the brightness of the luminophor, the energy distribution in which was obtained from the relation $\kappa \varepsilon\, G_{rm}$; the spectral class of this star was G_8. The energy distribution in its spectrum was taken to be that given by Planck, assuming its temperature T = 3840°, according to Brill's data [3]. Subsequently, L. M. Gindilis and I made a more thorough determination of the energy distribution in the spectrum of the luminophor by tie-ins with stars of type A_o having a well-known energy distribution. In the present work, all that was needed was the relative energy distribution over a comparatively narrow portion of the spectrum, so that any inaccuracies in the adopted energy distribution in εG_{em} scarcely affected the determination of the intensification of the brightness of the 5577 Å line in the spectrum of zodiacal light.

The magnitude of the intensification was calculated from the relation

$$k = \frac{2I_{zh}}{\overline{I_s} + \overline{I_N}}. \tag{1}$$

where J_{zL}, $\overline{J_S}$, $\overline{J_N}$ are the integral brightnesses of the 5577 Å line in the spectrum of zodiacal light in the southern and northern points of the sky, respectively, reduced to one instant.

The determination of the integral brightness of the 5577 Å line was made by calculating the area of the intensity distribution curve bounded by the contour of the line and the interpolated line of the intensity of the continuous spectrum. Graphs of this contour for zodiacal light and the sky are given in Fig. 5 for March 8, 1956. For the sake of clarity, the results of observations for one evening are shown in the graph (see Fig. 6), and the results for other days are given in Table 2 only. Fig. 6 shows the change in the brightness of the 5577 Å line in the spectrum of zodiacal light and sky for March 8, 1956 for 8 minutes of exposure (curves I, II and III). For that day of observations, the brightness of the 5577 Å line was determined for reference purposes, and for the 4 min exposures for the same portions of the sky as for the 8 min exposures (curves Ia, IIa, and IIIa). For the 8 min exposures, the values of the brightness of the 5577 Å line are given in units of brightness of the luminophor, and for the 4 min exposures, in relative units not converted into brightnesses of the luminophor, as the luminophor was found to be underexposed for the 4 min exposures.

By analyzing Fig. 6 one can conclude that the course of the change in the integral brightness of the 5577 Å line with time is the same for 4 min and 8 min within the limits of accuracy of the measurements, as can be seen by comparing lines I and Ia of the zodiacal light and III and IIIa for the sky at the southern point. The course of the integral brightness of the 5577 Å line for the point of the sky to the north of the axis of zodiacal

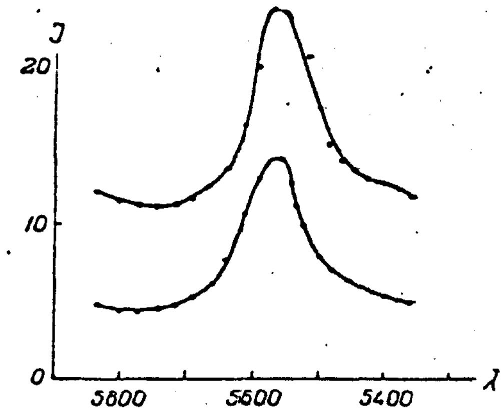

Fig. 5. Contour of the 5577 Å line for zodiacal light and the "southern" point of the sky.

light is quite different for 4 min and 8 min of exposure, apparently because of some defect in the emulsion of the plate for the first moment of observations (T = 7 hr 09 min). For the second moment of observations (T = 80 hr 05 min), the observations for the 4 min exposure are in agreement with the results obtained for the 8 min exposure, judging from the difference in the intensities of zodiacal light and sky at the northern and southern points.

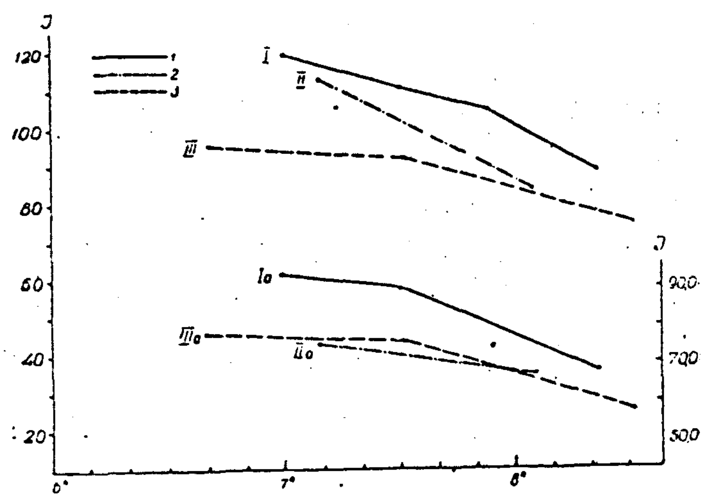

Fig. 6. Change in the integral brightness of the 5577 Å line as a function of time on March 8, 1956. Z = 70°. ————, zodiacal light; I, 8 min exposure; Ia, 4 min exposure; -•-•-•- Ia, sky to the north of the axis of zodiacal light; II, 8 min; IIa, 4 min; - - - - -IIa, sky to the south of the axis of zodiacal light; III, 8 min; IIIa, 4 min.

Therefore, in calculating the mean final intensities, the results of this observation of the northern point of the sky were rejected.

The values of the integral brightness of the 5577 Å line for 4 days of observations are shown in Table 2. For March 7, 10, and 14, 1956, the observed brightnesses are given in relative units, just as for March 8, 1956, for a 4 min exposure.

Table 2

Integral Brightness of the 5577 Å Line

1 Stellar time	2 J_s	3 J_n	4 J_{zh}
7/III 1956, exposure 8^m			
7 10		111,0	
7 25			116,8
7 36	97,3		
8/III 1956, exposure 4^m			
6 40	77,5		
6 59			92,1
7 09		77,4	
7 20			88,8
7 31	79,9		
7 53			72,2
8 05		65,6	
8 22			65,9
8 32	54,5		
8/III 1956, exposure 8^m			
6 40	96,7		
6 59			120,7
7 09		113,6	
7 20			111,7
7 31	93,3		
7 53			104,2
8 05		185,5	
8 22			89,2
8 32	77,2		
10/III 1956, exposure 16^m			
7 02	102,8		
7 24			107,6
7 44		107,9	—
14/III 1956, exposure 4^m			
7 46	98,8		
8 00			115,0
8 44		105,9	

The observations of March 10 and 14, 1956 were made at a zenithal distance of the slit center of 72°. Moreover, on March 10, 1956 the spectra were obtained on PF-3 film.

A comparison of the relative brightnesses of the 5577 Å line in the zodiacal light of the night sky was obtained as was indicated above, from formula (1), where $\overline{I}_S$ and $\overline{I}_N$ are the brightnesses of the 5577 Å line interpolated for the moment at which the zodiacal light was observed. The final results for the value of the intensification of the 5577 Å line are given in Table 3.

The columns of Table 3 represent the following: 1st column, stellar time for the middle of the exposure; 2nd column, integral brightness of the 5577 Å line on the axis of zodiacal light; 3rd column, $\frac{1}{2}(\overline{I}_S+\overline{I}_N)$, average brightness of the 5577 Å line for the sky, interpolated for the moment of observation of zodiacal light and for the azimuth of the point observed on its axis; 4th column, given value of k, characterizing the intensification of the 5577 Å line on the axis of zodiacal light; 5th column, angular distance of the observed point of zodiacal light from the Sun.

For the time of observation T = 7 hr 53 min, column 2 of Table 3 gives in parentheses the value of I_{zL}, taken from curve 1a of Fig. 6 and obtained by interpolation, and the corresponding value of the intensification in column 4 (also in parentheses).

An attempt to determine the accuracy of the results obtained was made in the following manner. First, the accuracy of the photometric measurements was determined. To this end, the photometry and determination of the integral brightness of the 5577 Å line were carried out 5 different times for a single case. The results of these measurements are given below.

Table 3

Intensification of the 5577 Å Line
on the Axis of Zodiacal Light

Serial No.	1 Stellar time	2 I_{zL}	3 $\frac{1}{2}(\bar{I}_s + \bar{I}_N)$	4 $k = \frac{2I_{zh}}{\bar{I}_s + \bar{I}_N}$	5 v
			7/III 1956		
1	7 25	116,8	104,2	1,11	50°
			8/III 1956, exposure, 4^m		
2	6 59	92,1	75,5	1,22	45
3	7 20	88,8	72,0	1,23	50
4	7 53	72,2(78,0)	66,5	1,07 (1,18)	55
5	8 22	65,9	59,0	1,12	60
			8/III 1956, exposure, 8^m		
6	6 59	120,7	95,0	1,27	45
7	7 20	111,7	93,0	1,20	50
8	7 53	104,2	88,0	1,18	55
9	8 22	89,3	80,0	1,12	60
			10/III 1956, exposure, 16^m		
10	7 24	107,6	104,9	1,07	40
			14/III 1956, exposure, 4^m		
11	8 00	115,0	102,3	1,13	50

Hence, the relative mean square error of one measurement of the integral brightness of the line is of the order of 3.3%. Let us now calculate the error in the value of k due to errors of the photometric measurements, proceeding from the formula

$$k = \frac{2I_{zL}}{\bar{I}_s + \bar{I}_N} = f(I_{zL}, \bar{I}_s\ \bar{I}_N).$$

The mean square error of k may be represented as follows:

$$\varepsilon_k^2 = \left(\frac{\partial f}{\partial I_{zL}}\right)^2 \varepsilon^2_{\bar{I}_z} + \left(\frac{\partial f}{\partial \bar{I}_s}\right)^2 \varepsilon^2_{\bar{I}_s} + \left(\frac{\partial f}{\partial \bar{I}_N}\right)^2 \varepsilon^2_{\bar{I}_N},$$

and the relative error is $\eta_k^2 = \frac{\varepsilon_k^2}{k^2}$.

Performing the transformations, we get

$$\eta_k^2 = \eta^2_{I_{zL}} + \frac{\bar{I}_s^2\, \eta^2_{\bar{I}_s} + I_{zN}\, \eta^2_{\bar{I}_N}}{(I_s + I_N)^2}.$$

Table 4

Serial No.	I_{5577}	ΔI
1	115,5	−2,3
2	114,9	−1,7
3	110,5	+2,8
4	115,8	−2,6
5	109,1	+4,1
Average	$\bar{I}_{5577}=113,2\pm1,7$	

We can now obtain η_k for one specific case, assuming that $\eta_{I_{zh}}=\eta_{I_N}=\eta_{I_s}=0,03$, and $J_N=111,0$, $I_s=97,3$. In this case, η_k = 0.04.

Thus, the error of one determination of k due to inaccuracies in the photometric technique attains 4%.

In view of the presence of sources of error other than those due to the photometry, such as the effect of irregularities in the grains of the plate, the inaccuracy in the estimate of the photographic fog, etc., it is more expedient to determine the accuracy of the result from the intrinsic similarity of the individual values of k for the four days of observations, the weighting being proportional to the number of observations.

Table 5

Date	k	Weight
7/III 1956	1,11	1
8/III 1956	1,19	8
9/III 1956	1,07	1
14/III 1956	1,13	1
Average	$=1,17\pm0,01_5$	

For March 8, 1956, the values of k shown in Table 5 were obtained by averaging all the values. For T = 7 hr 53 min, the value of k was taken as 1.18 $\pm$ 0.01 5. If, however, it is assumed to be 1.07, the average value obtained is k = 1.18 $\pm$ 0.02_5. From this one can determine the mean square error of one value for both cases. In the first case, it is found to be 0.05_4

(for the second case, 0.07_2). Assuming that the error of one determination of k $\varepsilon_k = 0{,}054$, the error of the average weighted value of k can be obtained from the formula

$$\varepsilon^2_k = \frac{\Sigma p_i^2 \varepsilon k_i^2}{(\Sigma p)^2}.$$

It is found to be $\pm\ 0.01_5$. This error does not take into account the dispersion of the values of k from one day to the next. In order to allow for this source of discrepancies also, a simple average was taken of the four values of k for the various days, and its error was computed from the intrinsic similarity; it was found to be

$$\overline{k_1} = 1{,}12 \pm 0{,}025.$$

The results obtained make it possible to conclude that, on the basis of the small number of observations cited above, the brightness of the 5577 Å line on the axis of zodiacal light is greater than the brightness of the sky at the same distance by an average of 12 to 17%.

On the basis of our observations as well as those of M. G. Karimov [1] and Roach et al [2], it can be assumed that the intensification changes appreciably from one night to the next and may sometimes be completely absent.

The variation of the brightness of the green line with time, which can in principle produce a systematic error, was minimized as much as possible in our technique by photographing the sky symmetrically in time with respect to the moment at which the zodiacal light was photographed. The possible systematic errors associated with the azimuthal course of the brightness of the sky were also essentially excluded, since the sky was photographed symmetrically with respect to the point of zodiacal light being studied. Variations in the brightness of the sky glow caused by differences in the zenithal distances were eliminated by choosing a single zenithal distance for all the pictures.

A more reliable estimate of the magnitude and stability of the intensification of the brightness of the 5577 Å line in the spectrum of zodiacal light requires a greater number of observations, and the pictures of zodiacal light and sky must be made simultaneously with prisms attached to the slit. It is also desirable to make the observations with a narrower slit, so as to be able to investigate the behavior of the 5893 Å line. We contemplate such work in the future.

In conclusion, I express my deep appreciation to academician V. G. Fesenkov and N. N. Pariiskii for valuable advice and comments, and also L. M. Gindilis for his participation in the observations and various laboratory investigations.

REFERENCES

1. Karimov, M. G., "Astronomicheskii zhurnal," 1950, vol. 25, iss. 97.
2. Roach, F. E., Pettit H. B., "Astrophys. Journal," Vol 119, No. 1, 253.
3. Brill, A. N., Bb. 223, 106.

ABSTRACT

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The comparison is made of integral brightness of the line 5577 Å of the nightglow for the axe of the Zodiacal light and for two points of the sky on the same zenith distance (70°).

Angular distances from the sun were 40-60°.

Integral brightness obtained with spectrograph of the high focal ratio 1:0.7 by integrating the tracing and substracting the intensity of the continuous spectrum. The spectrograms were taken during four evenings in March 1956.

Mean enhancement of the line 5577 Å in the Zodiacal light of 12-17% is received. A suggestion of a possible variability of the enhancement is made.

AUTHOR